

1 ALL-DEVICE-SPACE  
2 AUTOMATIC BLACK REPLACEMENT  
3  
4

5 RELATED PATENT DOCUMENTS  
6

7 Related documents are other, coowned U. S. utility-  
8 patent documents hereby incorporated by reference in their  
9 entirety into this document. One is in the names of Alex-  
10 ander Perumal and Paul H. Dillinger, and issued as U. S.  
11 5,657,137. Another is in the name of Paul H. Dillinger  
12 and issued as U. S. 5,377,024. Still others are in the  
13 name of Kent D. Vincent, U. S. 5,671,059; and in the names  
14 of Thomas H. Baker et al., as patent application serial  
15 09/183,819, later issued as U. S. 6,\_\_\_\_,\_\_\_\_. Yet anoth-  
16 er is in the names of Antoni Gil Miquel et al., and is  
17 patent application serial 09/642,417, later issued as  
18 U. S. 6,\_\_\_\_,\_\_\_\_.  
19  
20  
21

22 FIELD OF THE INVENTION  
23

24 This invention relates generally to machines and pro-  
25 cedures for incremental printing of text or graphics on  
26 printing media such as paper, transparency stock, or other  
27 glossy media; and more particularly to preparations for  
28 such printing, based upon data initially in the form of  
29 device-state color specifications — such as for instance  
30 four-color separations.

31 For the purposes of this document, and in particular  
32 the appended claims, "incremental printing" and "incremen-  
33 tal printer" encompass all printers and copiers that per-  
34 form directly computer-controlled construction of images

1 by small increments. Incremental printers thereby form  
2 images piecemeal, either directly on the print medium —  
3 as in the case of inkjet, dot-matrix or wax-transfer sys-  
4 tems — or on an electrostatically charged drum immediate-  
5 ly before transfer to the medium as in the case of laser  
6 printers. Thus by "incremental printer" and "incremental  
7 printing" it is intended to exclude printing presses and  
8 their operation, which transfer a whole image from a mas-  
9 ter negative or plate that is prepared previously in a  
10 separate operation using a different apparatus.

11 The present invention employs unique procedures to  
12 prepare four-color separations and like device-space data  
13 for use in incremental printing. The invention aims to  
14 avoid excessive grain in certain tonal ranges, for such  
15 input data, while preserving much of the actual-black  
16 colorant decisions expressed in such device-space data.

## 17 18 19 20 BACKGROUND OF THE INVENTION

21  
22 This invention addresses a special problem of exces-  
23 sive graininess in incremental printing of images initial-  
24 ly prepared for printing in terms of four-color separa-  
25 tions or equivalent. Four-color separations are in effect  
26 a device-space language, the language traditionally used  
27 for input data in make-ready procedures preliminary to  
28 printing-press operation.

29  
30 (a) "Ink thinkers" — Although printing-press tech-  
31 niques are definitely not the field of the present inven-  
32 tion, color printing-press technology has existed far  
33 longer and has long been one of the most popular areas of  
34 vocational training. Millions of people the world around

1 have been trained in the traditional field of graphic  
2 arts, and of letterpress or offset printing make-ready.

3 That training typically includes a very extensive set  
4 of protocols for design of colorant in a piece to be printed. Some of those protocols relate to the somewhat more  
5 traditional prepress technology of the process camera and  
6 its follow-on procedures — i. e. making and stripping up  
7 four-color negatives (including the so-called "bumping" of  
8 exposures to control final hardcopy quality), and exposure  
9 of printing plates through the finished negatives to produce  
10 press masters.  
11

12 Other protocols relate to more-modern procedures for  
13 generating negatives (or plates directly) in computer systems. All these procedures are highly elaborated, so that  
14 people who have learned them are actually able to remember  
15 a remarkable number of interactions among the pragmatic  
16 effects that result from various combinations of processing  
17 adjustments or refinements.  
18

19 In particular, overprinting of black or dark gray ink  
20 with a tone of some chromatic ink — such as, often, magenta — is known in the traditional graphic arts, especially  
21 for printing-press make-ready, as producing a striking  
22 and even compelling visual effect. The experience  
23 generated in the mind or eye of the final viewer is different  
24 from, and deeper than, might be predicted from the  
25 modern colorimetric theory that has grown up around incremental  
26 printing.  
27

28 Indeed, that modern theory by and large almost denies  
29 that there can be any physical meaning to a color produced  
30 by adding a chromatic colorant to a full or very nearly  
31 full black. Yet the artisans trained in the traditional  
32 printing-press arts know better, and may sometimes describe  
33 the result of such specialized overprinting tactics

1 as imparting extra "kick" or "punch" to an image — or as  
2 a "nonspectral" effect.

3 Thus, generally speaking, these trained people have  
4 been taught to think in terms of ink — the ink that will  
5 go into the press from cans, and that will be summoned out  
6 of the press and onto the paper (or other printing medium)  
7 by the exact character of images formed on the plates.  
8 Even though it is in principle a rather roundabout mental  
9 gymnastic, these artisans have studied and learned to con-  
10 ceptualize the final outcome of a printing job not on the  
11 basis of any theoretical perceptual color theory but rath-  
12 er on the basis of ink. They are the "ink thinkers".

13 The corps of personnel trained in these matters have  
14 learned quite sophisticated ways to produce fine effects  
15 in output hardcopies. It requires substantial investment  
16 in months and years of experience to be able to foretell  
17 how various small differences in film and plate prepara-  
18 tion will impact — several process steps and often one or  
19 two departments later — upon a stream of final hardcopies  
20 from a press.

21 Many of the individuals thus trained are extremely  
22 competent, and are justifiably proud of their abilities.  
23 Rightfully, they are well regarded as craftswomen and  
24 craftsmen in the highest sense.

25 As the technology of incremental printing has matured  
26 and acquired a certain dominance for short-run work, natu-  
27 rally many of those people have been attracted to this new  
28 field. It is only natural that those people should expect  
29 to bring with them the extremely extensive approaches that  
30 they spent their formative years learning. Those approa-  
31 ches are indeed remarkably powerful in the context of  
32 printing-press operations.

33



tems in at least one way and sometimes two distinct ways  
defeat the expectations of the ink-thinkers.

That subsection describes the customary use of perceptual color spaces in incremental printing. In preparation for that discussion, however, some additional facts about undercolor removal, graininess and black replacement will be helpful.

(c) Undercolor or gray-component removal, and graininess — Incremental printers are somewhat more sensitive than printing presses to generation of excessive graininess in highlight and midtone regions. This problem arises in rendition of the neutral component of a color.

By "neutral component" is meant to encompass not only light grays to midrange grays but also a portion of any color that has some common amount of all three subtractive primaries (cyan C, magenta M and yellow Y). It is well known that this common amount of three color inks — in purest colorimetric principle — can be replaced by a like amount of a single ink, namely black.

Such a replacement has recognized benefits. It reduces the total quantity of ink used and the associated expense, and in theory also provides a greater guarantee of actual colorimetric neutrality for the nominally neutral component.

Consequently such replacement, known as "undercolor removal" (UCR) or "undercolor replacement" has been made an automatic feature of many color-management schemes commonly used in incremental printing. Unfortunately terminology in this field varies considerably, but UCR usually refers to removal and replacement of the entire common quantity of the three subtractive primaries.

A related but somewhat more-general phrase, "gray-component replacement" (GCR), is usually used to refer to

1 removal and replacement of all or only part of the avai-  
2 lable common quantity of those three primaries. For pur-  
3 poses of simplicity in the remainder of this document,  
4 unless otherwise indicated by context all references to  
5 "UCR" will mean "UCR or GCR, or both, as appropriate".

6 As mentioned above, automatic UCR has been built into  
7 many printers. It is also well known, however, that in  
8 incremental-printing practice such a replacement has im-  
9 portant drawbacks:

10 For highlight and low-midtone regions, the resulting  
11 black ink dots — as compared with the colorimetrically  
12 equivalent grouping of color primary dots — intrinsically  
13 must be spaced relatively farther apart, thus appearing as  
14 graininess. Furthermore in some kinds of incremental  
15 printers (particularly inkjet printers) this is modernly  
16 aggravated by a trend for black pens to produce lower-  
17 quality image features than other pens.

18 (In the inkjet field, printheads are often called  
19 "pens" although they are far more complicated and sophis-  
20 ticated than the familiar unitary-writing-element model of  
21 e. g. a manually used ballpoint or fountain pen. For pur-  
22 poses of this document, except as otherwise indicated by  
23 context the term "pen" is to be understood as encompassing  
24 any incremental-printing printhead — whether inkjet or  
25 not, and even including a pagewide array.)

26 Reasons for this trend are not fully understood. It  
27 has been speculated that artifacts in black features are  
28 more visible simply because contrast is higher for black  
29 features generally, relative to the background.

30 In the printing-press world, by comparison, UCR is  
31 not a major problem. There, placement is extremely pre-  
32 cise and accurate; and moreover the inks and the printing  
33 media used in the printing-press field are much more for-

1 giving of representation of neutral components by black  
2 ink.

3 UCR-generated graininess, in particular, is at a very  
4 acceptable level in printing-press operations. Regretta-  
5 bly this cannot be said of UCR in the incremental-printing  
6 environment.

7  
8 (d) "Black replacement" or "BR" — Therefore in the  
9 incremental-printing field it has also become commonplace  
10 to institute certain limitations or exceptions to the use  
11 of UCR. In particular, it is known to pause in the proc-  
12 ess of establishing color rendition and replace quantities  
13 of tentatively established black, in highlights and mid-  
14 tones, with equivalent amounts of chromatic color.

15 Such a replacement is seen in the previously men-  
16 tioned patent of Perumal and Dillinger, who refer to  
17 "black replacement" (BR) and even to an extension of that  
18 approach, "black and secondary color replacement". The  
19 phrase "tentatively established", however, is very im-  
20 portant to understanding here — as Perumal and Dillinger  
21 do not reverse the entire regimen of replacements.

22 That is, they do not go so far as to remove black  
23 from any input color specification, i. e. anything that  
24 might be called "original" black. Hence for purposes of  
25 this document their use of phrases such as "black replace-  
26 ment", and also the short acronym "BR" as used in the  
27 present document, are strictly limited to the particular  
28 Perumal and Dillinger form of replacement, which means  
29 only replacement of an intermediate numerical value,  
30 representing a tentatively established quantum of black,  
31 in their calculations.

32 BR heretofore has been used only in those types of  
33 incremental printing that are based on original images  
34 generated or received through typical computer-graphics



1 programs — that is, programs which operate either in ad-  
2 ditive-primary (red R, green G and blue B) color space or  
3 in a perceptual color space such as CIELAB. A few other  
4 incremental-printing systems are controlled by alternative  
5 color spaces which are related to perceptual spaces or are  
6 special-purpose perceptual/device-space hybrids, as for  
7 instance the "hue plus gray" space introduced in the pre-  
8 viously mentioned patent of Dillinger.

9 Replacement of black by chromatics may possibly be  
10 known in the printing-press environment too, but if so it  
11 is discretionary and fully under control of the artisan.  
12 The number of personnel — if any — familiar with this  
13 technique for highlight regions is surely smaller than  
14 those familiar with, say, overprinting of a chromatic tone  
15 on top of black. The use of such replacement may be re-  
16 garded as a subtle effect, for extra-smooth highlights, as  
17 compared with such overprinting — which is instead a dra-  
18 matic effect.

19 Thus a good working knowledge of such replacement  
20 technique, if known at all in the printing-press environ-  
21 ment, may perhaps be confined to those workers needing  
22 enhancements for special applications such as fine-art  
23 reproduction projects. Because UCR is not usually a major  
24 problem in the printing-press environment, replacement of  
25 black by chromatics is not a simple necessity of life  
26 there — as it is in incremental printing.

27 Therefore this discussion is not at all intended to  
28 suggest that black replacement should be eliminated, when  
29 performing incremental printing based on device-space col-  
30 or specifications: very much the contrary is the case.  
31 In incremental printing heretofore, however, BR has been  
32 invoked automatically by a perceptual-color stage — dis-  
33 cussed below — and it is this grounding in customary per-  
34 ceptual theory that is objectionable.

(e) The colormap — This shorthand terminology "the colormap" is often used in referring to mapping or conversion of input color specifications into a perceptual or hybrid space for manipulation. For instance some computer-graphics programs receive inputs in the form of additive-RGB specifications and perform a transformation upon those numbers to derive equivalent perceptual values.

Then after complete manipulation the program reconverts the resulting colors into subtractive CMYK for printing. Programs of the colormap type dominate the incremental-printing field and in fact are sophisticated and extremely useful.

In fact such approaches have also been used in some computer programs that may be called "graphic arts" programs — which are specifically written to accept inputs in the form of subtractive device-space color data, and generate outputs that are nominally suitable for incremental printing. In other words, these programs are able to receive for instance four-color (usually CMYK) separations such as mentioned earlier.

Unfortunately passing such data into a colormap creates problems that are especially important and troublesome. These programs, just as in the RGB-input case, conventionally begin by converting the four-color separation data (or more generally subtractive device-space data) into a perceptual or hybrid space for manipulation. In fact sometimes these programs begin with an intermediate step of transforming CMYK inputs into RGB space, and then as usual converting to perceptual or hybrid space.

What is important to this discussion is not the exact order of events, but rather only the fundamental premise underlying the events. That premise is that perceptual space is the sole rational environment for color manipula-

tions, preparatory to final conversion into (or back into) printing-device space for operation of some apparatus.

This premise represents a major misstep in the implementation of four-color separations by incremental printing. When four-color separation data are converted into any conventional perceptual space, of necessity the conversion process discards information that is often crucial to the image-design thinking which previously went into formulation of the four-color separations.

This discarding — of a critical part of the intelligence embedded in those device-space specifications — is one of the two ways, mentioned in subsection (b) above, in which customary incremental-printing systems defeat the intentions of the ink-thinker. More specifically, once a four-color separation set has been translated into perceptual terms, the originally intended allocation of inks to image regions can no longer be reconstructed.

Consequently every special colorant effect created by the graphic artist or printing make-ready technician is destroyed in this process. As that technician or artist would see it, the job has simply been ruined.

(f) Gamut, and nonideal inks — The conclusions in the preceding paragraph are true even for a color that in principle could have been reproduced within the perceptual system — i. e. colors within the theoretical gamut of the perceptual system. In other words, what a printing device will do with such a color, if the device is controlled on the basis of this sort of perceptual system, is to make an at least plausible approximation of the specified color.

The artist or technician has wholly lost control of the quantity of black actually printed. Still, in defense of the system in such cases it is fair to say that within the limits of conventional perceptual rendition theory —

1 if not in terms of what can be perceived actually — the  
2 output color does correspond to the specified color.

3 Even in this case there are various degrees of fai-  
4 lure of the correspondence. For example, a so-called  
5 "process black" obtained by adding cyan C, magenta M and  
6 yellow Y inks — or in another notation "CMY" composite  
7 black — may often appear very slightly brownish rather  
8 than dead black; whereas on the other hand at least one  
9 particular black ink actually displays a very slight ma-  
10 genta cast.

11 In such situations it is fair to say that neither  
12 inking is ideal; however, this is precisely where the  
13 skill of the ink-thinker becomes invaluable. Such a  
14 craftsperson considers it an essential part of the work to  
15 become familiar with the actual behavior of one or some-  
16 times several given sets of inks, in a given printing sys-  
17 tem — an artistry largely lost upon users of perceptual  
18 systems.

19 Thereafter, for each printing job the ink-thinking  
20 artisan first judiciously selects the preferred visual ef-  
21 fect and then specifies the corresponding ink — or combi-  
22 nation of inks — within a selected ink set, to implement  
23 that desired effect. Of course such finesse is entirely  
24 foreclosed in prior-art systems that operate on a colormap  
25 basis.

26 As noted above, however, this is only the first of  
27 the two blows which a conventional incremental system  
28 deals to the experienced artisan who has come up through  
29 the printing industry. It is not the end of the story.

30  
31 The second defeat comes from the way in which a con-  
32 ventional perceptual-space system, in incremental print-  
33 ing, defines color gamut and relates that gamut to device  
34 spaces. In such systems an image region that is endowed

1 with a fully imprinted black has exhausted the available  
2 gamut of the system.

3 This comment should not be misunderstood as a state-  
4 ment about perceptual colorimetry in general. Of course  
5 when a spectrophotometer or proper colorimeter is used to  
6 measure the perceptual colorimetric content of an actually  
7 printed field of "full black" with an overprinted quantity  
8 of, say, magenta, such measuring apparatus clearly reports  
9 a colorimetric quantity which is very plainly different  
10 both from "full black" alone and from the overprinted  
11 quantity of magenta alone.

12 What is under discussion here is only the limited  
13 forward, preprinting perceptual-color theoretical formu-  
14 lation that is customary in incremental printing. Within  
15 the confines of this conventional preprinting analysis,  
16 "black" is a unique color that occupies the bottom tip of  
17 a three-color-dimensional solid representing the system  
18 gamut.

19 In effect, within this limited preprinting formula-  
20 tion, black represents the practical absence of light. To  
21 attempt any further removal of light from such a color, in  
22 this kind of theoretical regime, is an oxymoron if not a  
23 conundrum.

24 In other words, in algorithms following this approach  
25 as noted previously it is without physical significance to  
26 propose application of a subtractive colorant — whether  
27 more black, or any other colorant — to such a full-scale  
28 application of black. In machine programming that adheres  
29 to this perceptual-color type of preprinting analysis,  
30 black ink alone is enough to consume all available degrees  
31 of freedom (even though a four-color-separation input  
32 signal has three more degrees of freedom not yet  
33 deployed).

Here not only has the verbatim specification of desired color been lost, as in the preceding section (e), but even before that step the preprinting process of translation into perceptual space has truncated the input amplitude. In other words the perceptual-theory system has entirely clipped the input signal to black, even though an important part of the input signal called for an overprinted tone in addition to the black.

Since a system so programmed must consider the desired color to be out-of-gamut, no amount of adjustment or tinkering can possibly represent that desired color within a conventional perceptual space. If the color rendition discussed in the preceding section was fairly described as "ruined", then it remains to find adequate words for what is discussed here.

Since these special effects are difficult if not impossible to produce, it goes without saying that the printed hardcopy will not compare favorably with the results of a comparable project executed using a printing press. What is gone is that extra "punch" which the ink-thinker can now only visualize but never produce.

(g) Summary — In incremental printing, to prevent a grainy appearance black ink should not be used in midtone or highlight image regions. For a printer with an RGB-only interface, this desired preclusion of black ink is managed nicely through the colormap.

This route to blocking black ink out of highlight and midtone regions, however, is unworkable for a graphic-arts printer with a CMYK interface — or more generally for a printer that accepts four-color separations as inputs. The reason is that the artist or technician loses control over the amount of actual black ink generated.

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1 In such a system, process black (CMY) inputs and  
2 actual black (K) inputs are caused to become indistin-  
3 guishable. Naturally they come out the same, even though  
4 personnel preparing the ink specification have carefully  
5 designated them as different.

6 Any effort to colormap a preseparated CMYK specifica-  
7 tion necessarily always discards information about actual  
8 black ink. Depending on the specific colors called for,  
9 such an effort sometimes also clips the input color speci-  
10 fication before even beginning the transformation.

11 In short, four-color specs may be fed, willy-nilly,  
12 into colormaps — but cannot meaningfully pass through  
13 colormaps. Conventional colormap techniques are not ap-  
14 plicable to device-color CMYK incremental printers.

15  
16  
17 (h) Conclusion — As this discussion has shown, lim-  
18 itations in conventional incremental-printing color spaces  
19 continue to impede use of device-space specifications such  
20 as generated by craftspeople in the traditional printing  
21 industry — and thereby also continue to impede achieve-  
22 ment of excellent hardcopy generation competitive with  
23 printing-press products. Thus important aspects of the  
24 technology used in the field of the invention are amenable  
25 to useful refinement.

26  
27  
28  
29 SUMMARY OF THE DISCLOSURE

30  
31 The present invention introduces such refinement. In  
32 its preferred embodiments, the present invention has sever-  
33 al aspects or facets that can be used independently, al-

1     though they are preferably employed together to optimize  
2     their benefits.

3             In preferred embodiments of a first of its facets or  
4     aspects, the invention is a method of preparing for incre-  
5     mental printing of a color image. The phrase "incremental  
6     printing" is defined in an introductory section of this  
7     document.

8             The method includes the step of receiving or generat-  
9     ing data representing a device-color implementation of the  
10    image, including respective initial representations of at  
11    least black ink and chromatic-color inks. The method also  
12    includes the step of applying a substantially direct  
13    transform to:

14  
15                modify quantity of black ink represented in  
16                the data, and

17  
18                recombine the modified quantity of black  
19                ink with the initial representations.

20  
21             The word "substantially" is included here so that  
22     this description does encompass a method which includes  
23     some intermediate step that is insignificant in terms of  
24     black-ink data — i. e., a step that leaves the black-ink  
25     information available for direct processing in a subse-  
26     quent step. (Such perfunctory inserted steps are some-  
27     times included in machine-performed procedures simply in  
28     an effort to avoid patent claims.)

29             The foregoing may represent a description or defini-  
30     tion of the first aspect or facet of the invention in its  
31     broadest or most general form. Even as couched in these  
32     broad terms, however, it can be seen that this facet of  
33     the invention importantly advances the art.



1 In particular, by working with an initial black-ink  
2 quantity directly — that is, without first going through  
3 a preliminary transformation that obscures the original  
4 intent of a graphic artist or printing technician — this  
5 method preserves information about planned rendering of  
6 the image. Because this aspect of the invention in its  
7 broadest form thus refrains from tampering with decisions  
8 of such personnel, this invention resolves a previously  
9 discussed problem of the prior art.

10  
11 Although the first major aspect of the invention thus  
12 significantly advances the art, nevertheless to optimize  
13 enjoyment of its benefits preferably the invention is  
14 practiced in conjunction with certain additional features  
15 or characteristics. In particular, preferably the apply-  
16 ing step includes automatic modification of black ink rep-  
17 resented in the data in highlight and midtone regions of  
18 the image.

19 Another basic preference is that the applying step  
20 include automatic modification of two kinds of black-ink  
21 data: first, those same highlight/midtone black-ink data  
22 just mentioned — but for the particular purpose of miti-  
23 gating graininess in those regions — and second, black  
24 ink represented in the data in darker regions of the im-  
25 age. As to these latter regions, the purpose is instead  
26 to smoothly blend black-ink quantities in the darker re-  
27 gions with the modified quantities in the highlight and  
28 midtone regions.

29 In the case of this two-purpose preference, it is  
30 further preferred that the automatic modification of black  
31 include establishing (1) a black-ink onset point; and also  
32 (2) — for use in regions of an image darker than the on-  
33 set point — an increasing function of the initial repre-  
34 sentation of black ink. When this further preference is

in use, then it is yet further preferred that the automatic modification of black further include merging the function into substantially a black-identity function in darkest regions of an image.

Another preference, alternative to this last-mentioned merging, is that the applying step further include automatic modification of chromatic-color inks to accommodate the black-ink modifications. In this case it is still further preferred that the applying step include automatically recombining the modified quantity of black in a way that is inversely proportional to the initial representations of at least the chromatic-color inks.

If this inverse-proportionality preference is observed, then nested within it are two additional alternative preferences. In one of these, the "automatically recombining" includes finding in a lookup table new quantities of those representations, corresponding to the quantified black-modifying. In the other alternative preference, final ink representations  $C'$ ,  $M'$ ,  $Y'$  and  $K'$  for cyan, magenta, yellow and black respectively are found from the expressions:

$$C' = C + (1 - C) \cdot A_c(K)$$

$$M' = M + (1 - M) \cdot A_M(K)$$

$$Y' = Y + (1 - Y) \cdot A_v(K)$$

$$K' = A_x(K),$$

where C, M, Y and K are the initial representations of the same colors respectively, and  $A_c$ ,  $A_m$ ,  $A_y$  and  $A_k$  are respective preestablished automatic black-replacement functions.

We refer now to the first above-mentioned preference (dealing with automatic highlight/midtone black modification). Another subpreference, based upon that basic preference, is that the direct-transform application include

finding in a lookup table new quantities of the representations, corresponding to the quantified black-modifying.

In another basic preference, the method further includes the step of splitting at least one of the final ink representations, to implement the at least one representation in available light and dark colorants. In yet another basic preference, color initially having no black-ink component is passed through without modification.

In still another basic preference the method also includes the step of applying the data with recombined black ink in printmasking for hardcopy printing. One further preference, alternative to all the foregoing, will be mentioned: here the method also includes the steps of a human operator's manipulation of a control that selects an amount and a direction of black-ink modification — and thereafter, substantially automatic operation of the direct transform to effectuate the modifying and recombining parts of the applying step according to the operator's selection.

In preferred embodiments of its second major independent facet or aspect, the invention is an incremental printing system for forming an image by construction from dots deposited on a printing medium, based upon original image data in device-color space. It will be understood, from mention of the medium and the data in this form of a preamble, that they are parts of the operating environment of the invention rather than parts of the invention itself.

(In the accompanying claims generally the term "such" is used — instead of "said" or "the" — in the bodies of the claims, when reciting elements of the claimed invention, for referring back to features which are introduced

in preamble as part of the context or environment of the claimed invention. The purpose of this convention is to aid in even more distinctly and emphatically pointing out which features are elements of the claimed invention, and which are parts of its context — and thereby to more particularly claim the invention.)

This system includes a direct device-color to device-color computation module that is substantially automatic; this computation module modifies color image data with no manipulation in terms of perceptual color parameters. The system also includes an output incremental printing stage for printing the image from the modified data.

The foregoing may represent a description or definition of the second aspect or facet of the invention in its broadest or most general form. Even as couched in these broad terms, however, it can be seen that this facet of the invention importantly advances the art.

In particular, this aspect of the invention explicitly provides an incremental printing system that can accept as its input a set of device-state image specifications (such as for example color specifications prepared for use in a printing press) — and (because the computation module never manipulates data in perceptual terms) can do so without losing the device-color information embedded in the device-state specifications. This latter advantage is somewhat analogous to that of the first facet of the invention.

Although the second major aspect of the invention thus significantly advances the art, nevertheless to optimize enjoyment of its benefits preferably the invention is practiced in conjunction with certain additional features or characteristics. In particular, preferably the

automatic module includes an input for receiving the original image data in the form of initial four-or-more-color separations — and an output for directing four-or-more-color separations to the output stage.

Another basic preference is that the automatic module include a computation submodule for establishing (1) a black-ink onset point and (2) an increasing function of an initial amount of black ink, this function being for use in regions of an image darker than the onset point. In this case, preferably the automatic module further includes a computation submodule for merging the function into substantially a black-identity function in darkest regions of an image.

In preferred embodiments of its third major independent facet or aspect, the invention is an incremental printing method for forming an image by construction from dots deposited on a printing medium. This image forming is based upon original image data in device-color space.

The method includes the step of a direct device-color to device-color substantially automatic computation to modify color image data, with no manipulation in terms of perceptual color parameters. The method also includes the step of then incrementally printing a hardcopy image from the modified data.

The foregoing may represent a description or definition of the third aspect or facet of the invention in its broadest or most general form. Even as couched in these broad terms, however, it can be seen that this facet of the invention advances the art — supplying in essence the same advantages discussed above for the second aspect.

In preferred embodiments of its fourth major independent facet or aspect, the invention is an incremental-printing image-preparation method, for accommodating personnel who are accustomed to thinking in terms of ink combinations rather than in terms of numerical perceptual color models. The image is to be printed based upon an original image data file that substantially expressly represents inking to be used.

The method includes the step of receiving from those personnel an indication of quantity of black ink and other inks desired, in the form of at least four color separations, for use in incremental printing. The method also includes the step of -- in preparing for incremental printing -- directly and automatically implementing changes in represented quantity of black ink, for colors that initially have black ink.

The foregoing may represent a description or definition of the fourth aspect or facet of the invention in its broadest or most general form. Even as couched in these broad terms, however, it can be seen that this facet of the invention importantly advances the art.

In particular, the invention as considered in this fourth aspect addresses incremental-printing needs of a very large number of people initially trained in the traditional field of graphic arts and offset (or even letterpress) printing. As noted in the earlier "Background" section of this document, that training was extremely extensive and developed many sophisticated and highly elaborated approaches to colorant design.

Those approaches unfortunately cannot be realized within the framework of the more modernly arrived incremental printing — which instead of inking concepts has focused upon theoretically better-grounded perceptual-col-



1 tively small number of personnel, however, may possibly  
2 have learned to substitute chromatic colorants for black  
3 in highlight regions — particularly for applications such  
4 as fine-art reproduction work. In any event it is an  
5 enhancement to the efforts of ink-thinking artisans in  
6 general.

7  
8  
9 In preferred embodiments of its fifth major indepen-  
10 dent facet or aspect, as for the sixth, the invention is  
11 an incremental-printing image-preparation method, for ac-  
12 commodating personnel who are accustomed to thinking in  
13 terms of ink combinations rather than in terms of numeri-  
14 cal perceptual color models. As before, the image is to  
15 be printed based upon an original image data file that  
16 substantially expressly represents inking to be used.

17 The method includes the step of receiving from those  
18 personnel an indication of change in quantity of black ink  
19 desired, in incremental printing. It also includes the  
20 step of directly implementing the indicated change, in  
21 preparing for incremental printing.

22  
23 The foregoing may represent a description or defini-  
24 tion of the fifth aspect or facet of the invention in its  
25 broadest or most general form. Even as couched in these  
26 broad terms, however, it can be seen that this facet of  
27 the invention importantly advances the art.

28 In particular, this fifth aspect of the invention in  
29 a sense goes a step beyond what is accomplished in the  
30 fourth aspect. Whereas the fourth aspect simply accepts  
31 color separations as classically prepared by a traditio-  
32 nally trained graphic artist, the fifth aspect allows that  
33 artist to make adjustments in the inking directly and look  
34 at the results as printed.



1           Although the fifth major aspect of the invention thus  
2 significantly advances the art, nevertheless to optimize  
3 enjoyment of its benefits preferably the invention is  
4 practiced in conjunction with certain additional features  
5 or characteristics. In particular, preferably the indica-  
6 tion is substantially without reference to any perceptual  
7 color model.

8           In another basic preference, the implementing step  
9 includes automatic adjustment in quantities of chromatic  
10 inks, compensating for the indicated change in quantity of  
11 black ink. This compensating comprises substantially  
12 maintaining tonal values in areas of ink change; and the  
13 method also includes the step of applying the data file  
14 with the implemented change, to printmasking for hardcopy  
15 printing.

16  
17  
18           In preferred embodiments of its sixth major indepen-  
19 dent facet or aspect, the invention is an incremental  
20 printing system for forming an image by construction from  
21 dots deposited on a printing medium, based upon original  
22 image data in device-color space. The system operates un-  
23 der control of a user.

24           It includes a direct device-color to device-color  
25 graphical computer interface module for enabling the user  
26 to modify color image data in preparation for printing,  
27 without requiring the user to directly manipulate per-  
28 ceptual color parameters. It also includes an output in-  
29 cremental printing stage for printing the image from the  
30 modified data.

31  
32           The foregoing may represent a description or defini-  
33 tion of the sixth aspect or facet of the invention in its  
34 broadest or most general form. Even as couched in these

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1 broad terms, however, it can be seen that this facet of  
2 the invention importantly advances the art.

3 In particular, the advantages of this aspect of the  
4 invention are closely similar to those of the fifth facet,  
5 but arise from an implementation of the invention as ap-  
6 paratus rather than as a method. Although the sixth major  
7 aspect of the invention thus significantly advances the  
8 art, nevertheless to optimize enjoyment of its benefits  
9 preferably the invention is practiced in conjunction with  
10 certain additional features or characteristics.

11 In particular, preferably the interface includes con-  
12 trols that enable the user to set — substantially direct-  
13 ly — both a black-onset point; and an increasing function  
14 of an initial amount of black ink, for black-containing  
15 colors darker than the black-onset point. In this case it  
16 is further preferable that the interface further include  
17 controls that enable the user to substantially directly  
18 set merging of the above-described function with a black-  
19 identity function in darkest regions of the image.

20  
21  
22  
23 All of the foregoing operational principles and  
24 advantages of the present invention will be more fully  
25 appreciated upon consideration of the following detailed  
26 description, with reference to the appended drawings, of  
27 which:

1     BRIEF DESCRIPTION OF THE DRAWINGS

2  
3         Fig. 1 is a graph of an initial K function used in  
4     generating black replacement functions  $ABR_n(K)$ ; and with a  
5     black-identity function also shown for reference;

6         Fig. 2 is a like graph of a linear combination of the  
7     Fig. 1 function with the identity function, and again with  
8     the identity function also shown;

9         Fig. 3 is a graph of ABR functions for four colors,  
10    as used in a current product — again, shown together with  
11    the identity function;

12        Fig. 4 is a block diagram, very highly schematic and  
13    in fact a composite view showing both certain elements of  
14    a printer such as can be used at the factory to develop  
15    ideal ABR functions and graphs as in Figs. 1 through 3  
16    (however, this showing is only symbolic of the preferred  
17    actual embodiment, which currently employs a free-standing  
18    spectrophotometer rather than a carriage-mounted sensor),  
19    and also certain elements of a working system as thereaf-  
20    ter used in the field to print images based upon those ABR  
21    functions as fixed in the factory programming of the  
22    printer; thus this diagram illustrates practice of pre-  
23    ferred embodiments of the invention at two different  
24    stages; and

25        Fig. 5 is a like diagram, but showing only a printer  
26    as used in the field — and particularly one in which ABR  
27    functions are not wholly fixed at the factory but rather  
28    are subject to manual control. (In Fig. 5, two processing  
29    paths 74, 191ch-194ch shown in Fig. 4 are drawn cut away  
30    at 187 for reasons explained in the text.)

1 DETAILED DESCRIPTION  
2 OF THE PREFERRED EMBODIMENTS  
3  
4

5 1. ALL-DEVICE-SPACE AUTOMATIC BLACK REPLACEMENT  
6

7 Preferred embodiments of the present invention pro-  
8 vide the black replacement which is needed in inkjet and  
9 some other incremental-printing systems — but do so with-  
10 out leaving the device-space regime. Thus these embodi-  
11 ments can take the form of a direct CMYK-to-CMYK transform  
12 inserted in the device color path to perform automatic  
13 black replacement.

14 As the preferred embodiments perform automatic black  
15 replacement entirely within device space, they may be de-  
16 nominated "all-device-space automatic black replacement"  
17 or "ADSABR". This invention thereby resolves all the  
18 problems described in the earlier "Background" section of  
19 this document.

20 ADSABR substitutes color inks for black in the high-  
21 lights and midtones while maintaining pure device colors  
22 — i. e. this process by definition never goes into three-  
23 color space but rather always remains in four-space. Fur-  
24 thermore it performs this substitution while refraining  
25 from altering any purely chromatic input color. In other  
26 words, the invention does not affect any input color that  
27 contains no black.  
28  
29

30 2. PROBLEMS SOLVED, AND PRIOR-ART ATTEMPTS  
31

32 A six-color printer or raster image processor (RIP)  
33 that uses light colorants in a CMYKcm configuration — the  
34 lower-case letters denoting dilute or "light" colorants —

is unbalanced in the sense that the darkest ink, K, has no light counterpart as do the M and C inks. To avoid a grainy appearance, however, full-strength K ink must not be used in highlight image areas.

For printers with an RGB-only interface, the use of K ink(s) can be controlled through the colormap; but for graphic-arts printers that provide a device-color CMYK interface, colormap solutions are not possible — since the input is pre-separated and (as noted earlier) device colors do not pass through colormaps. ADSABR resolves this quandary through use of a direct CMYK-to-CMYK transform inserted in the device color path.

Restated, two types of prior solutions have been applied to the problem of highlight/midtone graininess in incremental printing:

- for RGB-only printers, K ink use is controlled in the colormap — a solution inapplicable to CMYK device color, which cannot pass through a colormap; and
- for CMYK printers, solutions have been implemented that convert CMYK to CMY or RGB first, and then apply black generation as usual (UCR otherwise) — and this processing affects all colors, even those that contain no K on input, so that the user loses control over black generation, and for instance the distinction between CMY and pure-K grays disappears.

Such loss of black-generation control and disappearance of the CMY/pure-K distinction are undesirable both because of graininess as such and also because of its aggravation in current inkjet systems by the relatively poorer image quality of K pens discussed above. Another problem dis-

1 cussed earlier is the occurrence of some color changes in  
2 the output.

3 ADSABR resolves all these difficulties by substitut-  
4 ing CMY for K only when necessary — i. e. for colors that  
5 do contain K on input — and by otherwise maintaining for  
6 the user the maximum possible control over device color.  
7 In the most highly preferred embodiment, the user can ex-  
8 ercise this control simply by the classical method of pre-  
9 paring four-color separations.

10 In alternative preferred embodiments, the user can  
11 exercise control over black generation by operating a man-  
12 ual override control. As will be seen, such a control is  
13 readily provided in the printing system as for example  
14 through a graphical user interface running in an associ-  
15 ated computer.

### 16 17 18 3. ALGORITHMIC BASIS

19  
20 ADSABR is the approach finally adopted by the present  
21 inventors for use in a current product of the assignee,  
22 the Hewlett Packard Company. ADSABR is a direct 4-to-4  
23 transform: all colors that have no K pass through this  
24 transform unmodified, and in the other colors K is re-  
25 placed by CMY, mainly in the highlights and midtones.

26 While the most-straightforward implementation may be  
27 real-time calculation, considerable computation time dur-  
28 ing incremental-printer operation can be saved by substi-  
29 tuting lookup-table equivalents. Once ADSABR tables have  
30 been defined, they are indexed by the input quantity K of  
31 black ink.

32 In use, each input K value specified by four-color-  
33 separations is then found in the table — or directly by  
34 computation — and four corresponding replacement numbers

ABR<sub>C</sub>(K), ABR<sub>M</sub>(K), ABR<sub>Y</sub>(K) and ABR<sub>K</sub>(K) from the table or computation are used. These numbers are not the actual output colors to be printed, but will be used in deriving those output colors as shown below. Each of these ABR (automatic black replacement) numbers may be called a "re-  
placement function" for a corresponding color plane C, M, Y or K respectively.

(a) Recombination — Development of the output numbers will be described shortly, but it is helpful to first jump ahead and see how they are preferably used. These output numbers are recombined with the original colors C, M, Y and K in an inverse proportional way to obtain the actual output colors C', M', Y' and K':

$$C' = C + (1-C) \cdot ABR_C(K)$$

$$M' = M + (1-M) \cdot ABR_M(K)$$

$$Y' = Y + (1-Y) \cdot ABR_Y(K)$$

$$K' = ABR_K(K)$$

In these four formulas, as above each of the expressions ABR<sub>N</sub>(K) represents a specific automatic black replacement function for device-color plane "N" (that is, for C, M, Y or K respectively). Of the four functions, the function ABR<sub>K</sub>(K) for K itself is central — and its development will be discussed with particular attention below.

With the ADSABR tables constrained to hold ABR<sub>K</sub>(0)=0, the desired passthrough behavior is ensured for colors that initially have no K. ADSABR functions, and their use in generation of ADSABR tables, resemble the generation of conventional UCR tables, with some subtle but significant differences. The first step consists in defining an initial ABR function k0 that will be used to constrain the solution:

1           (b) The initial form k0 — Choose an initial form of  
2 black-generation function k0(K) as shown below, the argu-  
3 ment K being the input quantity of black:

$$\begin{aligned} k0(K) &= 0 && \text{for } K < S, \\ &= L \cdot \left( \frac{K - S}{1 - S} \right)^P && \text{for } K \geq S \end{aligned}$$

8 in which S is the K-onset value,

9 L is the K-limit value, and

10 P is an exponent that determines the accelera-  
11 tion of output black in response to input  
12 black, above the onset value.

14 In essence the function k0(K) is simply an increasing  
15 function of K. One such function that has been found  
16 particularly effective and versatile, however, is a func-  
17 tion with a generalized exponent, as shown — that can be  
18 adjusted continuously among a great many possible values.

19 In practice, values exceeding unity, and preferably  
20 exceeding two, appear to be ideal. Analogously to devel-  
21 opment of UCR tables, choice of this initial black-genera-  
22 tion function is critical to generating good ADSABR val-  
23 ues, whether accomplished directly or through tables.

24 Inserting preferred magnitudes for the above param-  
25 eters — S = 0.4, L = 1 and P = 3 — the resulting function  
26 (Fig. 1) is typical for a six-color printer with the usual  
27 C, M, Y and K colorants, and also light C and light M. It  
28 is the nonzero value for the onset parameter S that re-  
29 flects the system designer's decision to delay the onset  
30 of true K ink in order to reduce the graininess of high-  
31 lights and midtones.

33 In other words, all blacks below the onset value S  
34 are rendered as process (CMY) black. As will be recalled,



1 a major motivation for the present invention is to restore  
2 to ink-thinkers the control they are accustomed to exert-  
3 ing over black ink. It may therefore appear ironic that  
4 development of the black-generation function — for the  
5 particular preferred embodiment under discussion — begins  
6 with, and focuses strongly upon, a designed-in mechanism  
7 for removing such control.

8 As explained earlier, however, inkjet and some other  
9 incremental printing systems are susceptible to undesired  
10 graininess in highlights and midtones, whereas a major  
11 thrust of the control-restoration philosophy revolves  
12 around overprinting chromatic shades in conjunction with  
13 black and dark grays. Thus the embodiment of the inven-  
14 tion represented in Fig. 1 attempts to restore control  
15 over black at the black end of the tonal range, where it  
16 is of greatest importance in classical (printing press)  
17 work, while at the same time curing the graininess problem  
18 that is a dominant concern in this technology.

19 In other words, the invention represents an effort to  
20 accommodate these two partly conflicting principles. (In  
21 alternative preferred embodiments the system operator may  
22 have a control switch for use in disabling the onset func-  
23 tion so that the black response over the entire range is  
24 identical to the black input.)

25  
26 It has been found, however, that better ADSABR tables  
27 are generated when the K function joins the K identity  
28 function near the full-black point — i. e. within the  
29 shadow end of the overall input-black range — rather than  
30 only at the full-black point. Such a merging of the K  
31 function with the identity function enables the system to  
32 invoke pure K without undercolor in the deep shadows (and  
33 also for pure-K text and line art).

This result smoothly integrates the desired highlight behavior with classical treatment of pure black ink in deep shadow. If, however, the graphic artist or technician has specified overprinting of an additional chromatic shade as discussed earlier, the response protocol under description preserves such overprinting.

This enhanced form of the invention can be achieved by a linear combination of the  $K$  function shown above with the identity function, as demonstrated below.

(c) A refined form  $k_1$  — Choose a variant form  $k_1(K)$  of black-generation function:

$$\begin{aligned}
 k_1(K) &= 0 && \text{for } K < S, \\
 &= k_0 \cdot \left[ 1 - \left( \frac{K - S}{M - S} \right) \right] + K \cdot \left( \frac{K - S}{M - S} \right) && \text{for } S \leq K \leq M, \\
 &= K && \text{for } S > M,
 \end{aligned}$$

where  $M$  is the "merge point" — at which the new  $K$  function is to merge with the identity function — and  $k_0$  and the other variables are as defined earlier.

With  $k_1$  defined as above and again a preferred value for the new parameter  $S = 0.95$  (Fig. 2), the proportion of  $K - S$  to  $M - S$  (a proportion that appears twice in the expression for  $k_1$ ) serves to moderate the midtone behavior, smoothly blending the intermediate curve into both pure  $k_0$  (and thereby output  $K = 0$ ) at the lower end and pure black at the upper. Thus when  $K$  is above the onset point  $S$  by only a small fraction of the interval from  $S$  to the merge point  $M$ , the ratio of  $K - S$  to  $M - S$  is very small, and only that very small fraction is subtracted (inside the square brackets) from unity — leaving the first term very nearly equal to the previously discussed function  $k_0$ .

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1 In that part of the range, however, by virtue of that  
2 same very small ratio, the second term is quite small and  
3  $k_1$  is not drawn significantly toward the identity value  $K$ .  
4 When  $K$  is almost at the merge point  $M$ , these relationships  
5 are reversed, so that the first term approaches zero while  
6 the second closely approximates the identity function  $K$ .

7  
8 Once the  $K$  function  $ABR_K(K)$  is defined, the CMY func-  
9 tions are obtained through numerical optimization, similar  
10 to the conventional process for UCR tables. The objective  
11 function being minimized is colorimetric difference be-  
12 tween (1) the resulting CMYK colors that correspond to a  
13 pure  $K$  input ramp, and (2) the actual color of a pure  $K$   
14 ramp.

15 Optionally it can also be attempted to gray-balance  
16 the result, using only the  $L^*$  component of the pure  $K$  ramp  
17 and setting the  $a^*$  and  $b^*$  components to zero. For the  
18 previously mentioned current product this was not done,  
19 since the goal was to affect color as little as possible  
20 while still reducing  $K$  graininess and banding.

21  
22 (d) Numerical optimization for CMY functions — In  
23 pseudocode, the optimization process looks for example  
24 like this iterative algorithm, performed for a moderate  
25 number of control points:

26  
27 let pitch = 1/32  
28 solution =(0,0,0)  
29  $K = \text{pitch}$   
30 minimize  $dE[\text{fwd}(0,0,0,K), \text{fwd}(c,m,y,k_1(K))]$   
31 variables:  $c,m,y$   
32 starting values: solution  
33 let solution =(c,m,y) corresponding to minimum found

```

1      let K = K + pitch
2      repeat until K = 1 - pitch.
3

```

4 In this notation, each of the two functions called out as  
5 "fwd" is a so-called "forward printer model". Although  
6 the concept and use of a forward printer model is known in  
7 the art, for completeness a very brief orientation appears  
8 in subsection (e) below.

9 For the previously mentioned current product, with a  
10 standard glossy printing medium and the k1 function shown  
11 in subsection (c) above, the four resulting ADSABR func-  
12 tions (Fig. 3) are the solution found by this iteration.

13 When the input is a pure K ramp, the output is iden-  
14 tical to the ADSABR functions. When the input contains no  
15 K or any color with one hundred percent K, the input pas-  
16 ses through unmodified. When the input contains colors  
17 with a K component between zero and one hundred percent,  
18 the K component is partially substituted with CMY, using  
19 the proportional-recombination formulas described in sub-  
20 section (a) above.

21  
22 (e) Forward printer models — Such a model relates  
23 device-independent color coordinates, such as CIELAB co-  
24 ordinates, to device-dependent color coordinates such as  
25 CMYK, and can be expressed as a simple function:

$$\text{fwd}(c,m,y,k) = (L,a,b).$$

26  
27  
28  
29 These models are commonly used — as in the iterative al-  
30 gorithm exhibited above — to evaluate the effect of vari-  
31 ous types of black treatment on image quality, and to gen-  
32 erate parameters or tables for the various models.

33 In some cases, rather than using a single function as  
34 shown above it is more convenient to consider each of the

1 CIELAB dimensions separately. The expressions may then  
2 take this form:

3  
4 
$$fL(c,m,y,k) = L$$

5 
$$fa(c,m,y,k) = a$$

6 
$$fb(c,m,y,k) = b.$$
  
7

8 Such models can be generated by conventional device-  
9 profiling software such as ColorSavvy RTKit (ProfilePrinter  
10 Deluxe), or constructed directly on the basis of colorimetric  
11 measurements, e. g. using Mathematica or Matlab. For the algorithm  
12 described here, the inventors have performed the modeling using  
13 Mathematica, and based on either IT8.7/3 measurements or equally-  
14 spaced CMYK measurements.

15 The inventors' models all used linear interpolation, and were all  
16 of the relative-colorimetric kind. In other words, the white-point  
17 reference is the unprinted printing medium — i. e., the blank paper  
18 (or other medium) always corresponds to CIELAB(100,0,0).  
19

20  
21 (f) ADSABR benefits and limitations — The inventors have  
22 evaluated a number of different ways of replacing pure K for  
23 incremental printers with CMYK device-color support. For the  
24 current product ADSABR was found to work best, for the following  
25 reasons.  
26

- 27 ■ It does not modify colors that do not contain K, and does not  
28 modify one hundred percent K — and thus it is the least  
29 impacting of the options. This is important for graphic-arts  
30 markets, in which designers and printers are accustomed to  
31 having complete control over device colors.  
32  
33

1     ■ In the intermediate black tonal range, it allows some  
2       measure of control over black generation for the  
3       user. Black generation is one of the most important  
4       control functions in printer-profile generation, and  
5       one for which look, feel and personal preferences  
6       play an important role.

7           Traditional approaches such as UCR divest the  
8           user of all control over black generation. That is a  
9           definite disadvantage for graphic-arts markets.

11       ■ It allows pure K to be replaced with CMY in midtones  
12       and highlights, in order to reduce graininess and/or  
13       mask banding or other artifacts that may be more vis-  
14       ible in K than in other colors. This accommodation  
15       of incremental-printing limitations appears both very  
16       important and also acceptable to the great majority  
17       of graphic-arts designers and printers — and fur-  
18       thermore can be made optional.

20 Achieving the best mode of practice for this inven-  
21 tion does require a thoughtful understanding of certain  
22 limitations of the ADSAER technique:

24     ▪ Highlight regions of pure-K grayscale images are  
25       transformed to four-color grayscale, which not only  
26       increases ink usage but may also create problems with  
27       gray balance.

29       ▪ Careful trial-and-error work is necessary to provide  
30       ADSABR tables that do not introduce problems with  
31       gray balance in general, or introduce artifacts in  
32       gradients. In particular, optimization is often  
33       fussy for gradients that move to or from combinations

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of a highly saturated primary or secondary with a considerable amount of K.

- If ADSABR is applied to the CMYK output of a printer profile (either internal or external to the printer), it will cascade with the black generation of the profile and delay the onset of K more than what that profile specifies. This may lead to problems with any profile that uses, in the vernacular, very "short" black. Such application is not intended.

On balance, ADSABR is a reasonable middleground approach to dealing with device-color control vs. graininess in six-color low-dyes printers.

#### 4. LOOKUP-TABLE IMPLEMENTATION

Subsections (a) through (c) above can be understood to describe computations actually performed in a production printer, in the field, when assigned the task of printing an image from four-color separations or equivalent data inputs. The same subsections can equally well be understood as describing computations performed only at the factory, in a representative or prototype printer, for the purpose of developing lookup tables from which the results of the computations can then be looked up, in the field, by each printer in a model line of printers — in lieu of performing the actual calculations over and over.

Thus instead of programming each production printer to perform the calculations, this form of the invention calls for programming of each production printer to look up the answers in the lookup tables. Programming to produce either procedure is well within the capability of a

competent senior programmer experienced in this field,  
given the instructions presented in this document.

The development of all four ABR(K) functions, and  
therefore the preparation of lookup tables, is taught in  
the preceding subsection 3. Nevertheless it may be help-  
ful to some people of ordinary skill in the art to see  
finished sets of the tables — which can alternatively be  
regarded as data corresponding to ABR curves of Fig. 3.

The following two tables are for glossy and coated  
media respectively, for all 256 levels (8 bit) of K input.  
The format is the usual C, M, Y, K — expressed in the  
range from zero through 255 — on each line. Each table  
contains 256 lines, the first line corresponding to input  
zero and the last to input 255.

glossy stock

0	0	0	0
1	1	1	0
2	2	2	0
3	3	4	0
4	4	5	0
5	5	6	0
6	6	7	0
7	7	8	0
8	8	10	0
9	9	11	0
10	10	12	0
11	11	13	0
12	12	15	0
13	13	16	0
14	14	17	0
15	15	18	0
16	16	19	0
17	17	21	0



20	18	19	22	0
	19	20	23	0
	20	21	24	0
	21	22	25	0
	22	23	26	0
25	23	25	27	0
	24	26	28	0
	25	27	29	0
	26	28	30	0
	27	29	31	0
30	28	30	32	0
	29	31	33	0
	30	32	34	0
	31	33	35	0
	32	34	36	0
35	33	35	37	0
	34	36	37	0
	35	37	38	0
	36	38	39	0
	37	39	40	0
40	38	40	41	0
	39	41	42	0
	40	42	43	0
	41	44	44	0
	42	45	45	0
45	43	46	46	0
	44	47	47	0
	45	48	48	0
	46	49	49	0
	47	50	50	0
50	48	51	51	0
	49	52	51	0
	50	53	52	0
	51	54	53	0

	52	55	54	0
	52	56	55	0
55	53	57	56	0
	54	58	57	0
	55	59	57	0
	56	60	58	0
	57	61	59	0
	58	62	60	0
60	59	63	61	0
	60	64	61	0
	61	65	62	0
	62	66	63	0
	63	67	64	0
65	63	68	65	0
	64	69	65	1
	65	70	66	1
	65	70	66	2
	66	71	67	2
70	67	72	68	2
	68	73	68	3
	68	73	69	3
	69	74	70	4
	70	75	70	4
75	70	76	71	5
	71	76	71	5
	71	77	72	6
	72	78	73	6
	73	78	73	7
80	73	79	74	7
	74	80	74	8
	75	81	75	9
	75	81	75	9
	76	82	76	10
85	76	82	77	10

	77	83	77	11
	78	84	78	12
	78	84	78	12
	79	85	79	13
90	79	86	79	14
	80	86	80	15
	80	87	80	15
	81	87	81	16
	82	88	81	17
95	82	89	82	17
	83	89	83	18
	83	90	83	19
	84	90	83	20
	84	91	84	21
100	85	91	84	22
	85	92	85	23
	86	93	85	23
	86	93	86	24
	87	94	86	25
105	87	94	87	26
	88	95	87	27
	88	95	88	28
	89	96	88	29
	89	96	89	30
110	89	97	89	31
	90	97	90	32
	90	97	90	33
	91	98	90	34
	91	98	91	35
115	92	99	91	36
	92	99	92	38
	93	100	92	39
	93	100	92	40
	93	100	93	41

120	94	101	93	42
	94	101	94	43
	95	101	94	45
	95	102	94	46
125	95	102	95	47
	96	102	95	48
	96	103	95	50
	97	103	96	51
	97	103	96	52
130	97	103	96	53
	97	103	96	55
	97	103	97	56
	98	104	97	58
	98	104	97	59
135	98	104	97	60
	98	104	97	62
	98	104	98	63
	98	104	98	65
	99	104	98	66
140	99	104	98	68
	99	104	98	69
	99	103	98	70
	99	103	99	72
	99	103	99	73
145	99	103	99	75
	99	103	99	77
	99	103	99	78
	100	103	99	80
150	100	103	100	81
	100	103	100	83
	100	103	100	84
	100	102	100	86
	100	102	100	88
	100	102	100	89

09071524 060410  
101090 12542860

	100	102	100	91
155	100	101	100	93
	100	101	101	94
	100	101	101	96
	100	101	101	98
	100	100	101	99
160	100	100	101	101
	100	99	101	103
	100	99	100	105
	99	98	100	106
	99	98	100	108
165	99	97	100	110
	99	97	100	112
	99	96	99	113
	99	95	99	115
	99	95	99	117
170	99	94	99	119
	98	93	98	121
	98	92	98	122
	98	92	98	124
	98	91	97	126
175	98	90	97	128
	98	89	97	130
	97	88	96	132
	97	87	96	133
	97	87	96	135
180	97	86	95	137
	96	85	95	139
	96	84	95	141
	96	83	94	143
	96	82	94	145
185	95	81	93	146
	95	79	93	148
	95	78	92	150

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T04090 42542860

	95	77	92	152
	94	76	92	154
190	94	75	91	156
	94	73	91	158
	94	72	90	160
	93	70	89	161
	93	69	89	163
195	93	67	88	165
	93	65	87	167
	93	64	87	169
	92	62	86	171
	92	60	86	173
200	92	58	85	174
	92	56	84	176
	91	53	83	178
	91	51	83	180
	91	49	82	182
205	90	46	81	184
	90	44	80	185
	90	42	79	187
	89	39	79	189
	89	36	78	191
210	89	33	77	193
	88	30	76	194
	88	28	75	196
	88	25	75	198
	87	22	74	200
215	87	19	73	201
	87	17	72	203
	87	15	72	205
	87	13	71	206
	87	12	71	208
220	88	10	70	210
	88	8	70	211

09674524 06040  
10+090" 42542360

	88	6	69	213
	88	4	69	215
	89	3	68	216
225	90	3	68	218
	90	2	68	219
	91	2	67	221
	92	2	67	223
	93	1	66	224
230	94	1	66	226
	94	0	66	227
	96	0	65	229
	97	0	65	230
	99	0	65	231
235	101	0	65	233
	102	0	64	234
	104	0	64	235
	106	0	64	237
	107	0	64	238
240	111	0	64	239
	115	0	65	240
	119	0	66	242
	122	0	67	243
	126	0	68	244
245	130	0	69	245
	134	0	70	246
	137	0	71	247
	141	0	72	248
	145	0	73	249
250	149	0	74	250
	153	0	75	251
	156	0	76	252
	160	0	77	253
	164	0	78	254
255	168	0	79	255

coated stock

	0	0	0	0
	1	1	1	0
	1	2	2	0
	2	2	3	0
5	3	3	3	0
	4	4	4	0
	4	5	5	0
	5	5	6	0
	6	6	7	0
	6	7	8	0
10	7	8	9	0
	8	9	10	0
	8	9	10	0
	9	10	11	0
	10	11	12	0
15	11	12	13	0
	11	13	14	0
	12	13	15	0
	13	14	16	0
	13	15	16	0
20	14	16	17	0
	15	17	18	0
	15	17	19	0
	16	18	20	0
	17	19	21	0
25	18	20	22	0
	18	21	22	0
	19	21	23	0
	20	22	24	0
	20	23	25	0
30	21	24	26	0
	22	24	27	0



	23	25	27	0
	23	26	28	0
	24	27	29	0
35	25	28	29	0
	25	28	30	0
	26	29	31	0
	27	30	31	0
	27	31	32	0
40	28	31	33	0
	29	32	33	0
	29	33	34	0
	30	34	34	0
	31	34	35	0
45	32	35	36	0
	32	36	36	0
	33	37	37	0
	34	37	37	0
	34	38	38	0
50	35	39	39	0
	36	40	39	0
	36	41	40	0
	37	41	40	0
	38	42	41	0
55	38	43	42	0
	39	44	42	0
	40	44	43	0
	41	45	43	0
	41	46	44	0
60	42	47	44	0
	43	48	45	0
	43	48	46	0
	44	49	46	0
	45	50	47	0
65	45	50	47	0

09374524 160401  
104090 12542860

	45	51	47	1
	46	52	48	1
	46	52	48	2
	47	53	48	2
70	47	53	49	2
	48	54	49	3
	48	54	49	3
	49	55	50	4
	49	56	50	4
75	50	56	50	5
	50	57	50	5
	51	57	51	6
	51	58	51	6
	52	58	51	7
80	52	59	52	7
	53	59	52	8
	53	59	52	9
	54	60	52	9
	54	60	53	10
85	55	61	53	10
	55	61	53	11
	56	62	53	12
	56	62	54	12
	57	62	54	13
90	57	63	54	14
	58	63	54	15
	58	63	54	15
	59	64	55	16
	59	64	55	17
95	60	64	55	17
	60	65	55	18
	60	65	56	19
	61	65	56	20
	61	66	56	21

100	62	66	56	22
	62	66	56	23
	63	66	56	23
	63	67	57	24
	63	67	57	25
105	64	67	57	26
	64	67	57	27
	64	67	57	28
	65	68	57	29
	65	68	57	30
110	65	68	57	31
	66	68	58	32
	66	68	58	33
	66	68	58	34
	67	68	58	35
115	67	69	58	36
	67	69	58	38
	68	69	58	39
	68	69	58	40
	68	69	58	41
120	68	69	58	42
	69	69	58	43
	69	69	58	45
	69	69	58	46
	69	69	58	47
125	70	69	58	48
	70	69	58	50
	70	69	58	51
	70	69	58	52
	71	68	58	53
130	71	68	58	55
	71	68	58	56
	71	68	58	58
	71	68	58	59

	71	68	58	60
135	71	68	57	62
	71	68	57	63
	72	68	57	65
	72	68	57	66
	72	67	57	68
140	72	67	57	69
	72	67	57	70
	72	67	57	72
	72	67	56	73
	72	66	56	75
145	72	66	56	77
	72	66	56	78
	72	65	55	80
	72	65	55	81
	72	65	55	83
150	72	64	55	84
	72	64	55	86
	72	64	54	88
	72	63	54	89
	72	63	54	91
155	72	62	53	93
	72	62	53	94
	72	61	53	96
	72	61	52	98
	72	60	52	99
160	72	59	51	101
	71	59	51	103
	71	58	51	105
	71	57	50	106
	71	57	50	108
165	71	56	49	110
	71	55	49	112
	71	55	48	113

	71	54	48	115
	71	53	47	117
170	71	52	46	119
	71	51	46	121
	70	50	45	122
	70	49	44	124
	70	48	44	126
175	70	48	43	128
	70	46	42	130
	70	45	41	132
	70	44	40	133
	69	43	40	135
180	69	41	39	137
	69	40	38	139
	69	39	37	141
	69	38	36	143
	69	36	35	145
185	69	35	34	146
	69	34	33	148
	68	32	33	150
	68	31	32	152
	68	30	31	154
190	68	28	30	156
	68	27	29	158
	68	26	28	160
	68	25	27	161
	68	24	27	163
195	68	23	26	165
	68	22	25	167
	69	21	24	169
	69	20	24	171
	69	19	23	173
200	69	18	22	174
	69	16	21	176

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104090" 42542860

	69	15	20	178
	69	13	19	180
	69	12	18	182
205	70	10	17	184
	70	9	16	185
	70	8	15	187
	70	7	14	189
	70	6	13	191
210	71	5	12	193
	71	4	11	194
	71	3	9	196
	71	2	8	198
	72	1	7	200
215	72	0	6	201
	72	0	5	203
	72	0	4	205
	71	0	3	206
	71	0	3	208
220	71	0	2	210
	71	0	1	211
	70	0	1	213
	70	0	0	215
	69	0	0	216
225	69	0	0	218
	68	0	0	219
	67	0	0	221
	67	0	0	223
	66	0	0	224
230	65	0	0	226
	65	0	0	227
	63	0	0	229
	61	0	0	230
	60	0	0	231
235	58	0	0	233

	57	0	0	234
	55	0	0	235
	53	0	0	237
	52	0	0	238
240	47	0	0	239
	42	0	0	240
	37	0	0	242
	31	0	0	243
	26	0	0	244
245	21	0	0	245
	16	0	0	246
	11	0	0	247
	9	0	0	248
	8	0	0	249
250	7	0	0	250
	5	0	0	251
	4	0	0	252
	3	0	0	253
	1	0	0	254
255	0	0	0	255

# 1 5. HARDWARE/PROGRAM ENVIRONMENT

2

3 As the invention is amenable to implementation in, or

4 as, any one of a very great number of different printer

5 models of many different manufacturers, little purpose

6 would be served by illustrating a representative such

7 printer. If of interest, however, such a printer and some

8 of its prominent operating subsystems can be seen illus-

9 trated in several other patent documents of the assignee,

10 Hewlett Packard — such as for example the previously men-

tioned document of Antoni Gil Miquel, which particularly illustrates a large-format printer-plotter model.

In some such representative printers, a cylindrical platen 41 (Fig. 4) — driven by a motor 42, worm and worm gear (not shown) under control of signals from a digital electronic processor 71 — rotates to drive sheets or lengths of printing medium 4A in a medium-advance direction. Print medium 4A is thereby drawn out of a supply of the medium and past the marking components that will now be described.

A pen-holding carriage assembly 20 carries several pens, as illustrated, back and forth across the printing medium, along a scanning track — perpendicular to the medium-advance direction — while the pens eject ink. For simplicity's sake, only four pens are illustrated; however, as is well known a printer may have six pens or more, to hold different colors — or different dilutions of the same colors as in the more-familiar four pens. The medium 4A thus receives inkdrops for formation of a desired image.

A very finely graduated encoder strip 33, 36 is extended taut along the scanning path of the carriage assembly 20 and read by a very small automatic optoelectronic sensor 37 to provide position and speed information 37B for one or more microprocessors 71 that control the operations of the printer. One advantageous location for the encoder strip, shown in earlier coowned patent documents of the assignee, is immediately behind the pens.

A currently preferred position for the encoder strip 33, 36, however, is near the rear of the pen carriage — remote from the space into which a user's hands are inserted for servicing of the pen refill cartridges. For either position, the sensor 237 is disposed with its opti-



cal beam passing through orifices or transparent portions of a scale formed in the strip.

The pen-carriage assembly 20, 20' is driven in reciprocation by a motor 31 — along dual support and guide rails (not shown) — through the intermediary of a drive belt 35. The motor 31 is under the control of signals from the processor or processors 71.

Preferably the system includes at least four pens holding ink of, respectively, at least four different colors. Most typically the inks include yellow Y, then cyan C, magenta M and black K — in that order from left to right as seen by the operator. As a practical matter, chromatic-color and black pens may be in a single printer, either in a common carriage or plural carriages.

Also included in the pen-carriage assembly 20, 20' is a tray carrying various electronics. Fig. 4 most specifically represents a system such as the Hewlett Packard printer/plotter model "DesignJet 2000CP", which does not include the present invention. These drawings, however, also illustrate certain embodiments of the invention, and — with certain detailed differences mentioned below — a printer/plotter that includes preferred embodiments of the invention.

Before further discussion of details in the block diagrammatic showing of Fig. 4, a general orientation to that drawing may be helpful. This diagram particularly represents preferred embodiments of one previously discussed apparatus aspect of the invention.

Conventional portions of the apparatus appear as the printing stage 20 through 51, and 4A, discussed above, and also the final output-electronics stage 78 which drives that printing stage. This final-output stage 79 in turn is driven by a printmasking stage 171, which allocates

1 printing of ink marks 18, 19 as among plural passes of the  
2 carriage 20, 20' and pens across the medium 4A.

3 Also generally conventional is a nonvolatile memory  
4 175, which supplies operating instructions 66 (many of  
5 which are novel and implement the present invention) for  
6 all the programmed elements; and also four-color separa-  
7 tion data 70, at far left in the diagram, made up of pre-  
8 separated K, C, M and Y color-plane data arrays. These  
9 data flow as input signals 191 into the processor 71.

10 Features particularly related to the apparatus aspect  
11 of the invention appear in the central region of the di-  
12 agram as elements 72 through 78, 82, 83, 187, and 192  
13 through 195; these will be detailed below. Given the  
14 statements of function and the diagrams presented in this  
15 document, a programmer of ordinary skill — if experienced  
16 in this field — can prepare suitable programs for operat-  
17 ing all the circuits.

18  
19 The features enumerated in the preceding three para-  
20 graphs are those features generally found in a production  
21 printer in the field. In addition, features used only at  
22 the factory in prototype or representative printers — in  
23 printers of the sort here described that are dedicated to  
24 graphic-arts use — include test-pattern-generating cir-  
25 cuitry 63, 80, as well as a data path 65 for information  
26 that results from reading of test patterns by a small col-  
27 orimeter sensor 51, or the like, that also travels on or  
28 with the pen carriage.

29 As noted earlier, for this invention the embodiment  
30 that is most highly preferred at present actually makes  
31 use of an entirely free-standing photometer which is ca-  
32 pable of colorimetric measurements at highest possible  
33 precision and accuracy. Another preferred embodiment of  
34 the present invention, however, makes use of a carriage-

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1 mounted high-quality colorimeter such as taught in the  
2 patent documents of Vincent or particularly Baker, men-  
3 tioned above.

4 Such read-out data pass to a test-pattern reading al-  
5 gorithm 81, in a particular module 72 of the processor 71.  
6 Test-pattern data received from the path 65 and read by  
7 the algorithm 81 are used in derivation 82 of the black-  
8 generation function — and also in the forward-model it-  
9 eration for the chromatic-color functions — to generate  
10 the expressions, curves and lookup tables 83 already  
11 described.

12 One or more of these various forms 83 of the ABR for-  
13 mulation are then stored in the nonvolatile memory 175 of  
14 a production printer. There the ABR information guides  
15 the operation of that printer after it has been installed  
16 and placed in use in the field.

17  
18 The pen-carriage assembly is represented separately  
19 at 20 when traveling to the left 16 while discharging ink  
20 18, and at 20' when traveling to the right 17 while dis-  
21 charging ink 19. It will be understood that both 20 and  
22 20' represent the same pen carriage, with the same pens.

23 The previously mentioned digital processor 71 pro-  
24 vides control signals 20B, 20'B to fire the pens with cor-  
25 rect timing, coordinated with platen drive control signals  
26 42A to the platen motor 42, and carriage drive control  
27 signals 31A to the carriage drive motor 31. The processor  
28 71 develops these carriage drive signals 31A based partly  
29 upon information about the carriage speed and position  
30 derived from the encoder signals 37B provided by the en-  
31 coder 37.

32 (In the block diagram all illustrated signals are  
33 flowing from left to right except the information 37B, 65  
34 fed back from the sensors 37, 51 — as indicated by the

1 associated leftward arrows — and analogously the previ-  
2 ously mentioned information 66, 83, whose direction is  
3 likewise nonstandard.) The codestrip 33, 36 thus enables  
4 formation of color inkdrops at ultrahigh precision during  
5 scanning of the carriage assembly 20 in each direction —  
6 i. e., either left to right (forward 20') or right to left  
7 (back 20).

8  
9 New image data 70 are received 191 into an image-pro-  
10 cessing stage 73 — which conventionally would include a  
11 colormap module, a contrast and color adjustment or cor-  
12 rection module, and a rendition module using dithering or  
13 error diffusion to determine a tone value to be printed at  
14 each pixel. In some embodiments of the present system,  
15 the rendition may be all worked out in advance and ex-  
16 pressed in the separate KCMY planes of the input data; and  
17 an objective of the present invention is to preserve as  
18 much of that expression as is consistent with graininess  
19 characteristics of incremental printing.

20 That is the assumption followed — only for tutorial  
21 simplicity's sake — in preparation of Fig. 4 (and Fig. 5  
22 as well); however, it is to be understood that equivalent-  
23 ly additional, conventional processing stages may be in-  
24 cluded, and the drawings are to be interpreted as showing  
25 such other conventional stages. These may include rendi-  
26 tion (e. g. dithering or error diffusion), ink limiting  
27 (e. g. depletion), color-saturation enhancement (e. g.  
28 propleton) and various other forms of signal modification  
29 in incremental printing, whether or not now known.

30 For present purposes, the processing stage 73 imple-  
31 ments the ADSABR decision-making and adjustments described  
32 above, applying the described technique with respect to  
33 each individual color specification received. That is, in  
34 effect the incoming color data path 191 is first bifurca-

ted within the processing stage 73, into two principal paths:

- a black-ink data input path 191K, and
- a chromatic-ink data input path 191ch.

At the output (right) end of the ADSABR stage 73, these two paths exit as 194K and 194ch respectively, and then reconverge as an output 194 that is shown as unitary. It will be understood, however, that just as the input signal 70, 191 actually contains four separated KCMY data planes, the output 194 similarly presents four separate data sets to the previously mentioned masking stage 171.

Now reverting to the input (left) end of the ADSABR stage 73, there the black input path 191K is in turn trifurcated 192:

- if a particular input color has no black ( $K = 0$ ), then that color signal is diverted to a passthrough path 74 — and accordingly is passed through to the output path 194 unchanged;
- if a particular input color is all black, or nearly so (this criterion relates to the merge value " $\underline{M}$ ", and is expressed above as " $K > \underline{M}$ "), then that color signal is analogously diverted to another passthrough path 78 and similarly passed through to an output point 193 (where the two pass-through paths 74, 78 join), and is likewise unchanged; but
- if, however, the amount of black in an input color is in the intermediate range (that is, if  $0 < K < \underline{M}$ ),



lute colorants). At no point in this system are perceptual-space manipulations or colormap operations introduced; hence the prefix "ADS" (all-device space) in the title of the "ADSABR individual-color processing stage".

As mentioned earlier, the processing stage 73 does not necessarily itself perform in real time the actual calculations indicated. This stage may instead simply process the input data by looking up the necessary answers in lookup tables — typically held in the memory module 175. Thus Fig. 4 represents both these kinds of processing, which as viewed from outside the processing stage 73 are functionally identical.

As suggested earlier in the description of drawings, the components that have now been discussed are typically present in production printers as found in the field. They are included as well in prototype and like preliminary forms of a product under development in the factory.

The upper section of the same drawing, however, includes features that may be included in only the latter development-environment devices (although some production machines may also have similar modules used for field calibration maintenance and the like) — or that may encompass some elements of an entirely free-standing colorimeter. These features include an algorithm module 63 and control-signal path 80 for operating the output stage 79 and printing stage to make test patterns; and a complementary data-return path 65 and analytical modules 72, 81, 82 for reading and using data returned from such patterns.

The returned data 65 are applied by these analytical modules 72, 81, 82 to derive the ADSABR parameters S, P and M. These parameters are then forwarded 83 for storage in the operating memory 175, which sends control signals 66 to the processing modules 74-78 discussed above.

1           Although this fully automatic embodiment of the in-  
2           vention is most highly preferred, and is very effective  
3           and satisfactory in operation, an alternative preferred  
4           embodiment adds an opportunity for greater control by the  
5           human operator using the printer. Thus a manual override  
6           or fine-tuning block 300 (Fig. 5) may be beneficially pro-  
7           vided if desired.

8           The override module 300 may take the form of a graph-  
9           ical user interface (GUI) — for instance of the Windows®  
10          or Macintosh® variety — as illustrated. Alternatively  
11          the override module 300 may instead take any of numerous  
12          other well-known forms such as for example Linux, Unix or  
13          DOS control screens, or even a hardwired control system  
14          with physical switches, potentiometers etc.

15          One way, but by no means the only one, to implement  
16          manual control is simply to patch the user into the param-  
17          eter set S, P, M that has been described above. Thus the  
18          user may be enabled to send the first color-processing  
19          subblock 76 an S-value signal 108 by controlling a K-onset  
20          value-setting module 102.

21          (In Fig. 5, the previously discussed "no black" proc-  
22          essing path 74 and chromatic-ink path 191ch-194ch — see  
23          Fig. 4 — have been drawn cut away at 187-187 so as to  
24          permit clearer showing of the S-value signal path 108.  
25          Other signals 208, 308 discussed below are also revealed  
26          more clearly by this interruption of paths 74, 191-194ch.)

27          To send such an S-value signal 108, the user operates  
28          a manual-input unit 103. This unit 103 if present prefer-  
29          ably includes a slider or a stepper switch 104. Again,  
30          the stepper or slider may be implemented as an on-screen  
31          selector in a personal-computer GUI, or in the other ways  
32          enumerated above if preferred — e. g. as an actual elec-  
33          tromechanical slider or switch.



In either event the stepper or slider 104 preferably operates along a scale 105 accompanied by indicia 106, 107 to expressly present to the user the implication of trading-off granularity against more-literal adherence to the input black specifications. In the drawing, for example, it has been suggested that a minimal value 106 of the K-onset number S may be associated with "high K fidelity", and a maximal value 107 associated with "low grain".

This is a logical association, since a zero value of S makes true black ink K appear at the output 194 whenever any black K appears at the input 191 — and a very high value causes input black K to be replaced by less-grainy process black CMY even into midtones and beyond. On the other hand, there are many other equivalent ways of labeling a control 104 and associated scale 105.

These include, for instance, simple mechanically descriptive legends such as "K onset" for the entire scale, and "0" at the left end 106 and "1" at the right end 107. Another approach is to label the left end "follow 4-color separations" and the right end "smooth highlights", etc.

Similarly additional control paths 208, 308 for the exponent P and high-end merge point M can be fed from analogous value-setting modules 202, 302 respectively. Each of these may in turn be operated by manual-control units 203, 303 respectively — which if desired may match the K-onset control unit 103 in operation and also in user labeling.

If preferred, the controls or their labels, or both, may take different respective forms related to the underlying differences between the natures of the parameters S, E and M. Thus for instance toggle switches, and discrete-value selectors using radio buttons and the like, are all equivalents.

Specific wordings and forms of labels 206, 207, 306, 307 shown for the latter two parameter selections — like those offered in the drawing for the K-onset scale — although logical are merely exemplary and a matter of esthetics, judgment and design choice. It will be understood that the system is entirely capable of operation with no manual-input provision 103-108, 203-208, 303-308 at all, if design philosophy undertakes to establish automatically as in Fig. 4 an ideal or acceptable setting for each parameter.

The invention is not limited to operation in four-colorant systems. To the contrary, for example six-colorant "CMYKcm" systems including dilute cyan "c" and magenta "m" colorant are included in preferred embodiments.

The integrated circuits 71 may be distributive — being partly in the printer, partly in an associated computer, and partly in a separately packaged raster image processor. Alternatively the circuits may be primarily or wholly in just one or two of such devices.

These circuits also may comprise a general-purpose processor (e. g. the central processor of a general-purpose computer) operating software such as may be held for instance in a computer hard drive, or operating firmware (e. g. held in a ROM 175 and for distribution 66 to other components), or both; and may comprise application-specific integrated circuitry. Combinations of these may be used instead.

The above disclosure is intended as merely exemplary, and not to limit the scope of the invention — which is to be determined by reference to the appended claims.